Spin-orbit angles, and the aligned-misaligned transition

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David Brown

A C Cameron, M Gillon, M Lendl,
G R M Miller, B Smalley, A H M J Triaud

University of St Andrews

600 YEARS

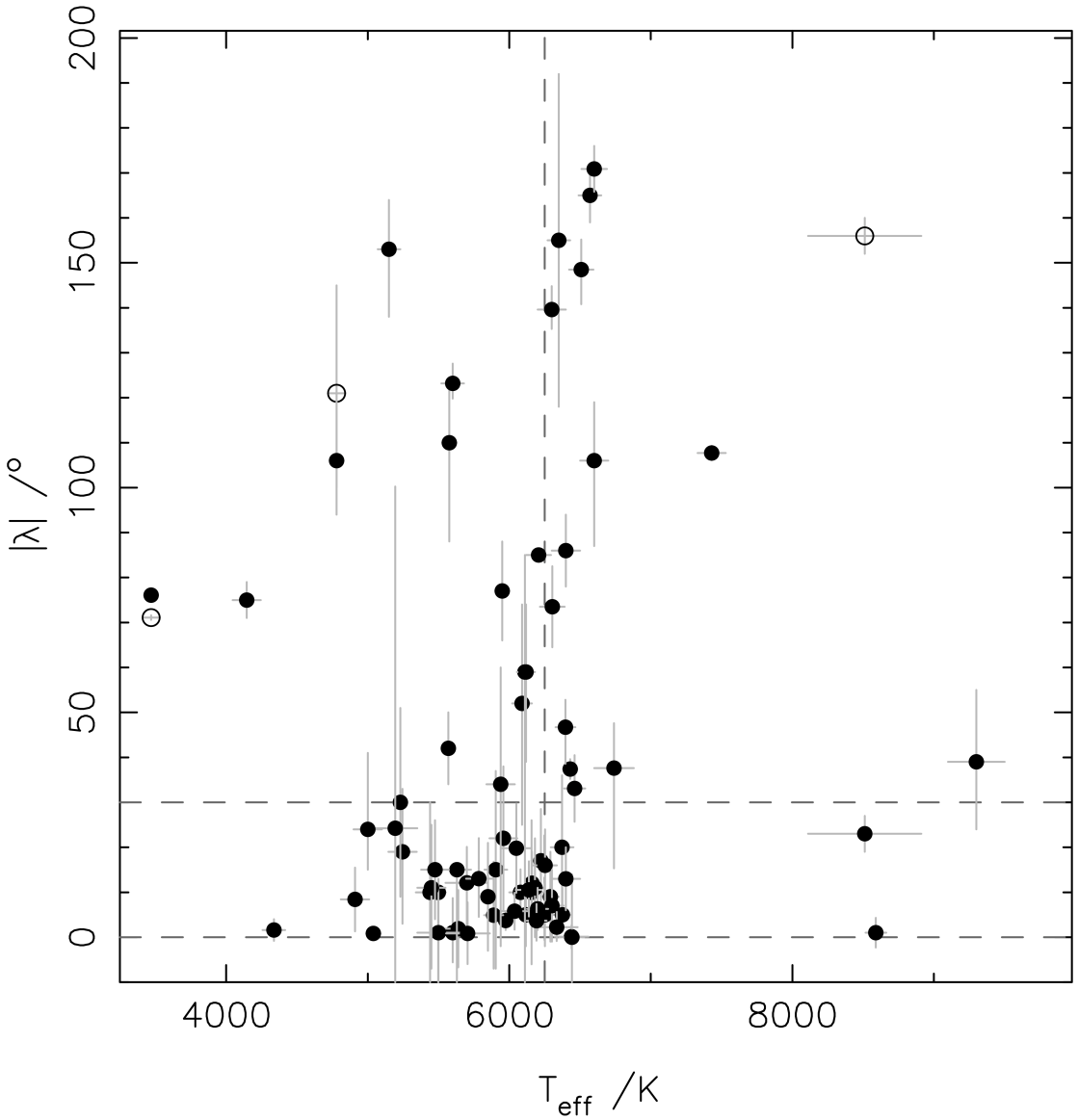
Science & Technology Facilities Council

SUPA

‘Hot’ vs ‘cool’

- Trend of projected alignment angle, λ, with T_{eff}
  - Boundary at $T_{crit} \approx 6250$ K (Winn et al. 2010)
  - ‘Hot’ stars preferentially host planets in misaligned orbits.
    - $\lambda > 30^{o}$
  - ‘Cool’ stars preferentially host planets in aligned orbits.
    - $\lambda \leq 30^{o}$

‘Hot’ vs ‘cool’

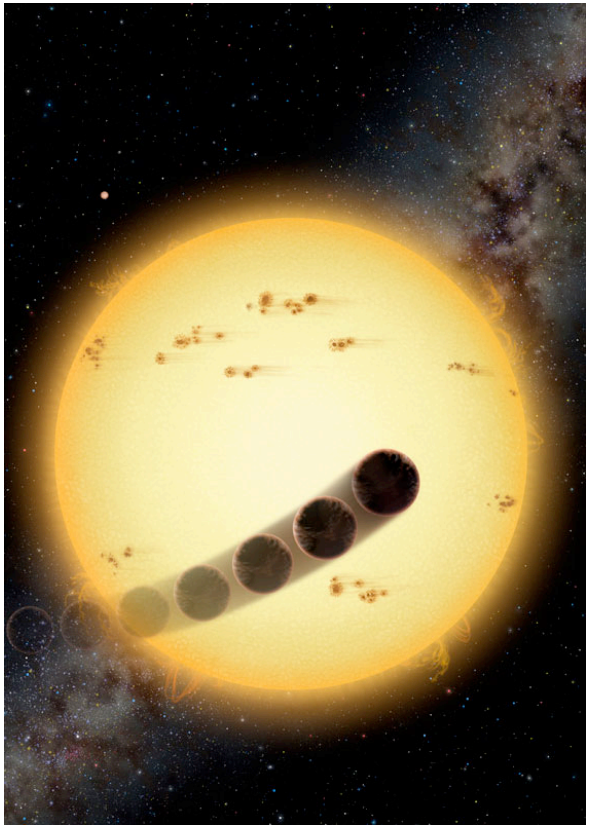


‘Hot’ vs ‘cool’

- Trend of projected alignment angle, λ, with T_{eff}
  - Boundary at $T_{crit} \approx 6250$ K (Winn et al. 2010)
  - ‘Hot’ stars preferentially host misaligned planets.
    - $\lambda > 30^{o}$
  - ‘Cool’ stars preferentially host aligned planets.
    - $\lambda \leq 30^{o}$
- Boundary loosely coincides with disappearance of convective envelope.
  - Tidal realignment?

Target sample

- New observations of 6 WASP systems.
  - 6000 K ≤ T_{eff} ≤ 6600 K.
  - Aim to precisely measure λ using multiple models.



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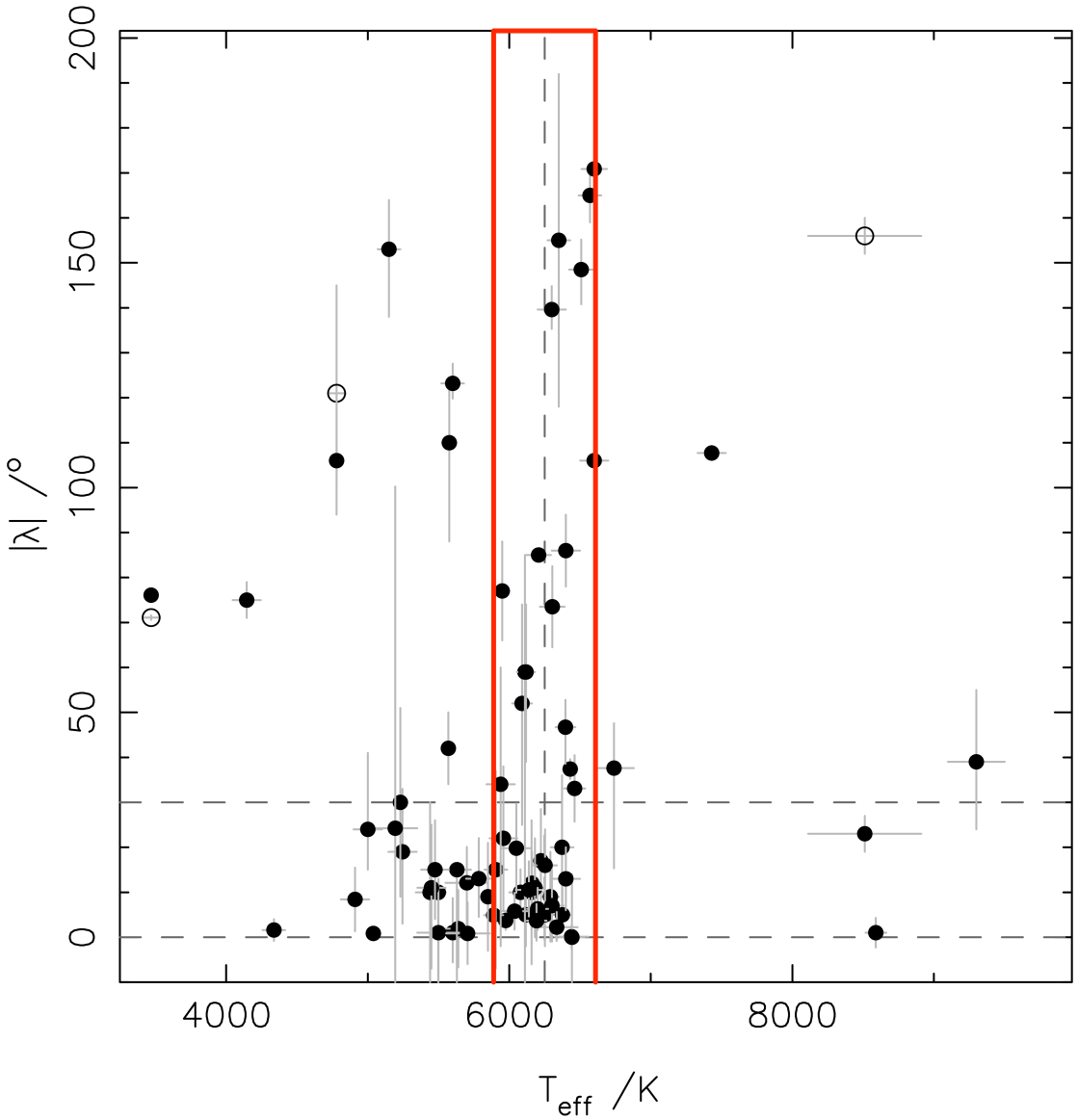
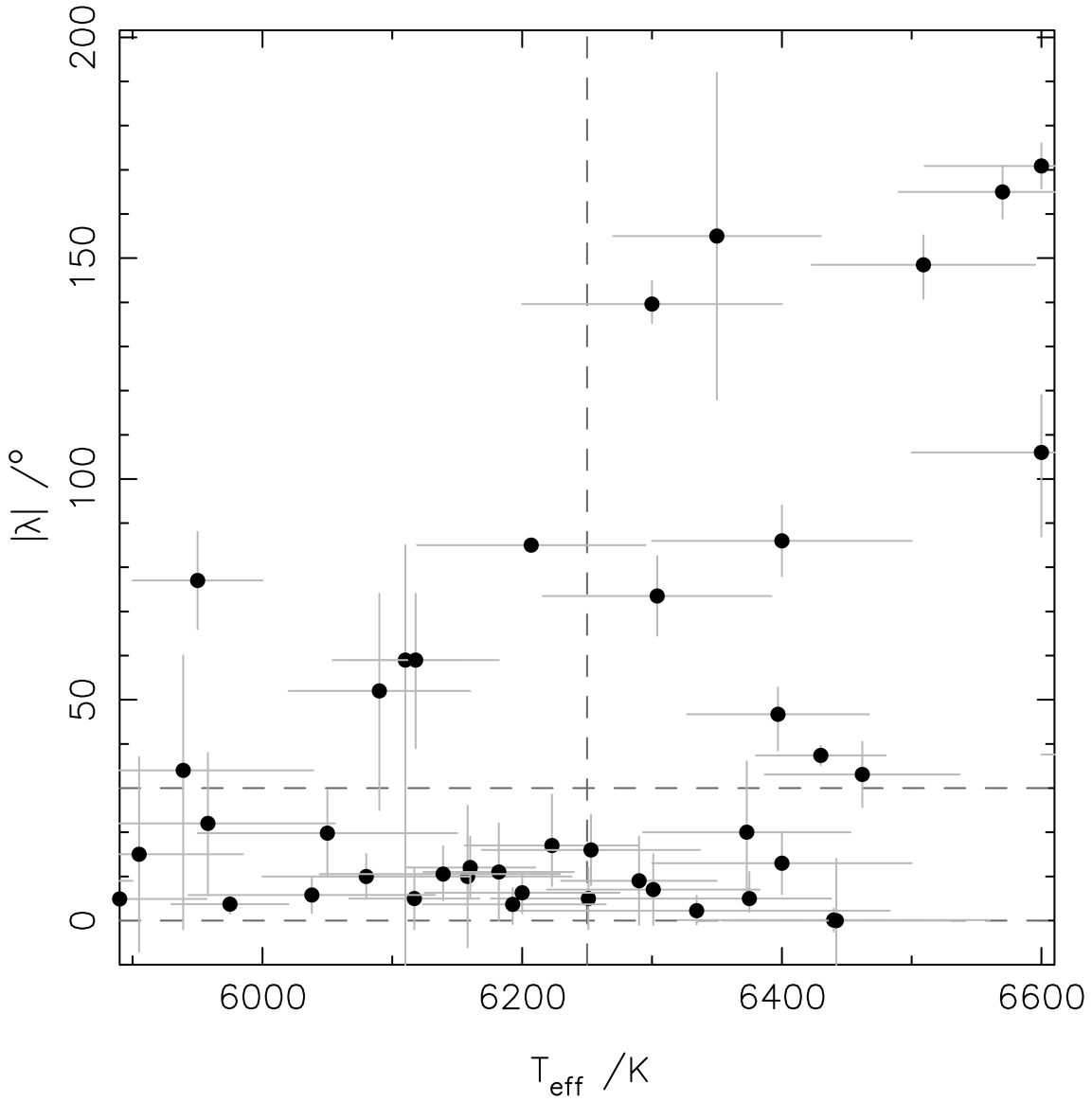
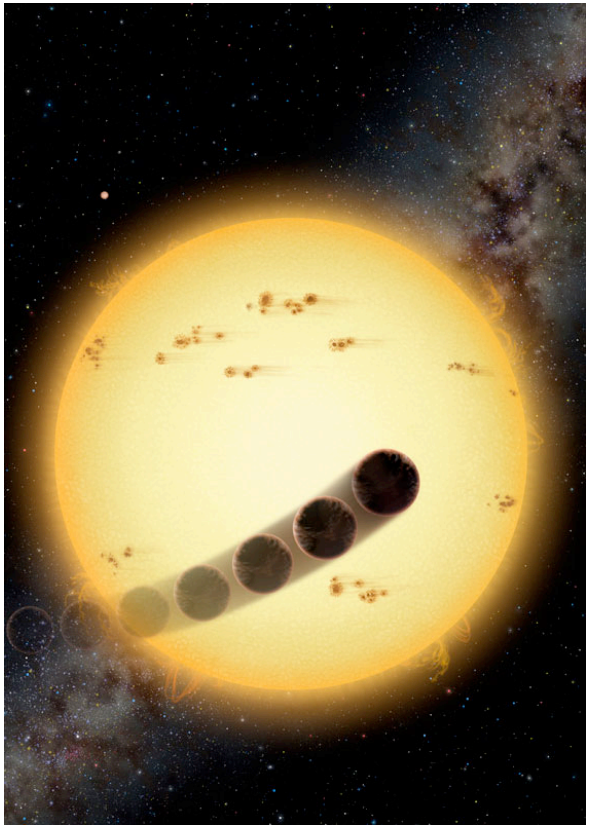


‘Hot’ vs ‘cool’



Target sample

- New observations of 6 WASP systems.
  - 6000 K ≤ T_{eff} ≤ 6600 K.
  - Aim to precisely measure λ using multiple models.
- One transit per target observed using HARPS.
  - Additional observations help constrain RV curve and long-term drift.

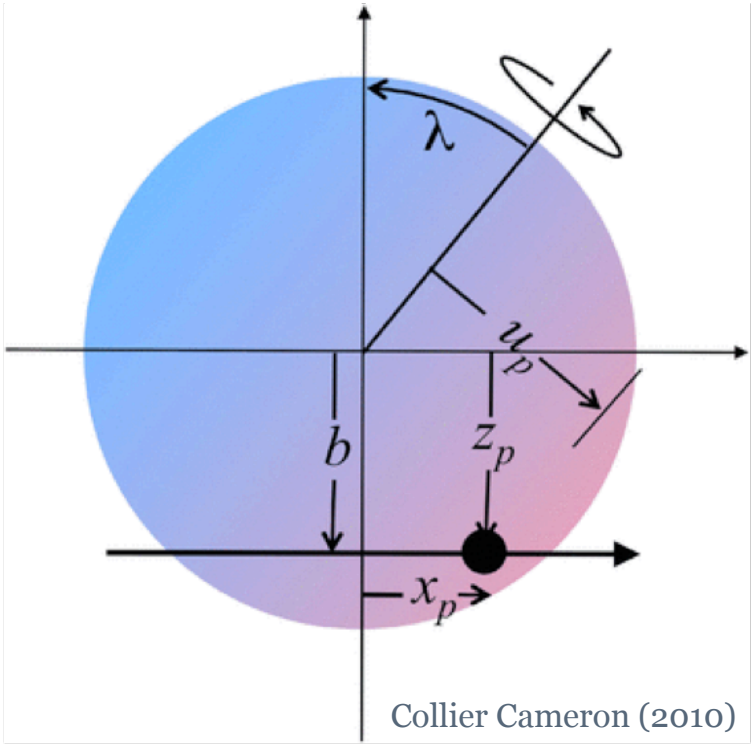


Target sample

- WASP-61
  - T_{eff} = 6250 ± 150
  - vsinI = 10.3 ± 0.5
- WASP-62
  - T_{eff} = 6230 ± 80
  - vsinI =8.7 ± 0.4
- WASP-71
  - T_{eff} = 6050 ± 100
  - vsinI = 9.4 ± 0.5
  - λ = 20.1 ± 9.7
    (Smith et al. 2013)
- WASP-76
  - T_{eff} = 6250 ± 100
  - vsinI = 3.3 ± 0.6
- WASP-78
  - T_{eff} = 6100 ± 150
  - vsinI = 7.2 ± 0.8
- WASP-79
  - T_{eff} = 6600 ± 100
  - vsinI = 19.1 ± 0.7
  - $\lambda = -106\ ^{+10}_{-8}$
    (Addison et al. 2013)

Methods

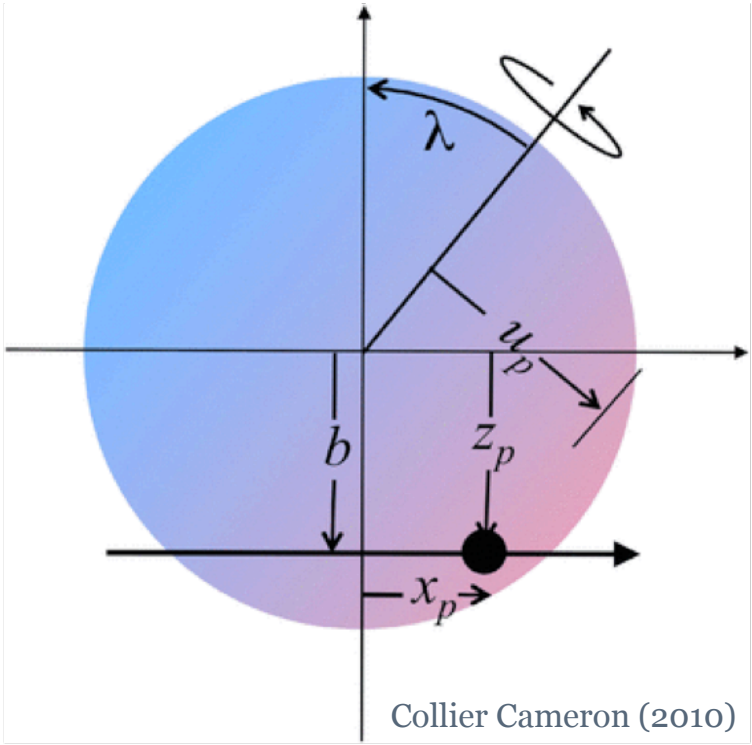
- Combined analysis of photometric and spectroscopic data.
- Spectroscopy provides:
  - vsinI
  - λ
- Photometry constrains:
  - Transit duration
  - Impact parameter, b
  - Stellar and planetary radii
  - Ephemeris



Collier Cameron (2010)

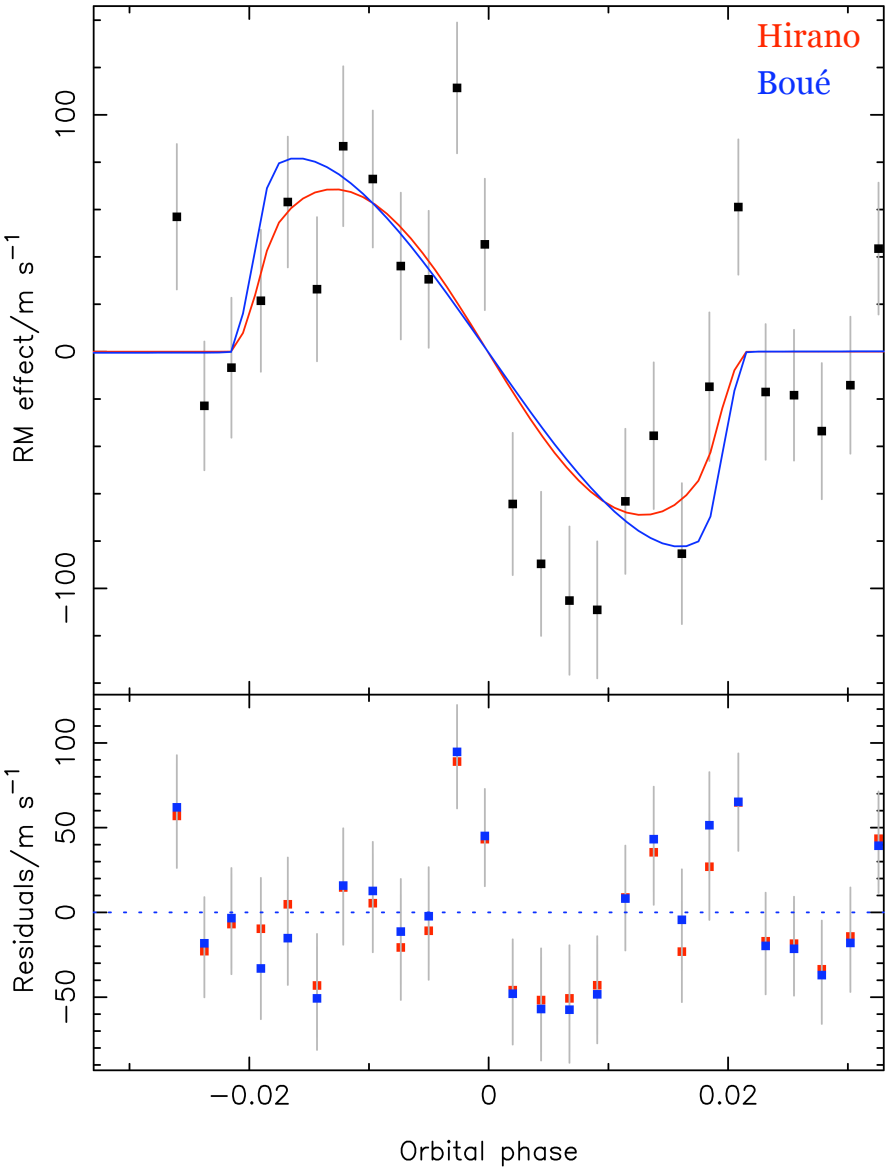
Methods

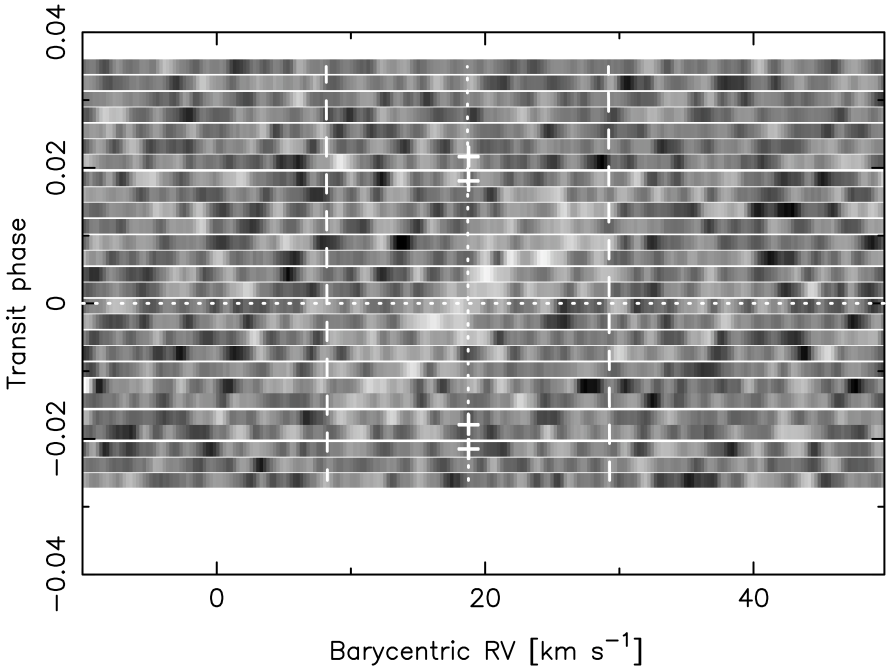
- Rossiter-McLaughlin effect.
  - Hirano et al. (2011) model.
  - Boué et al. (2013) model.
  - Model radial velocity anomaly produced during transit.
- Doppler tomography.
  - Collier Cameron et al. (2010)
  - Directly models 'missing' light.
  - Breaks degeneracy between vsinI and λ in low b systems.



Collier Cameron (2010)

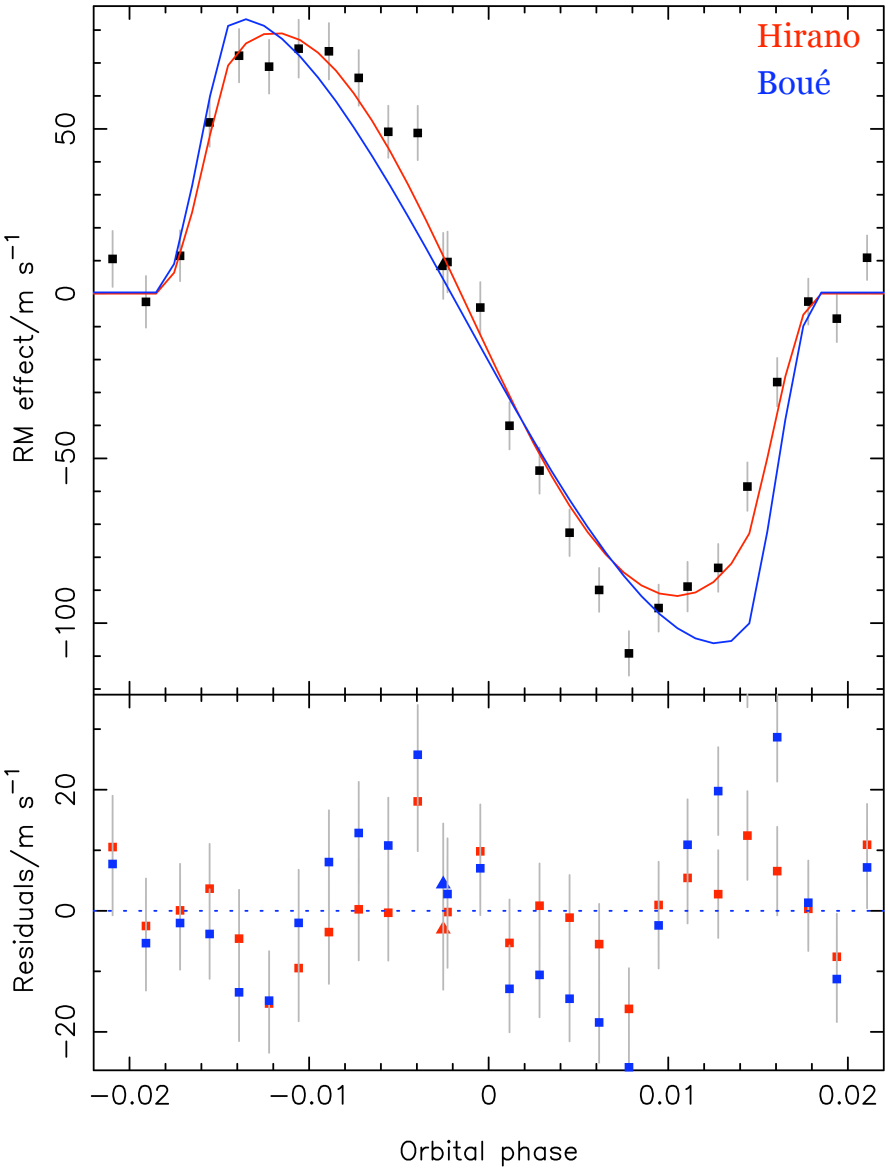
WASP-61

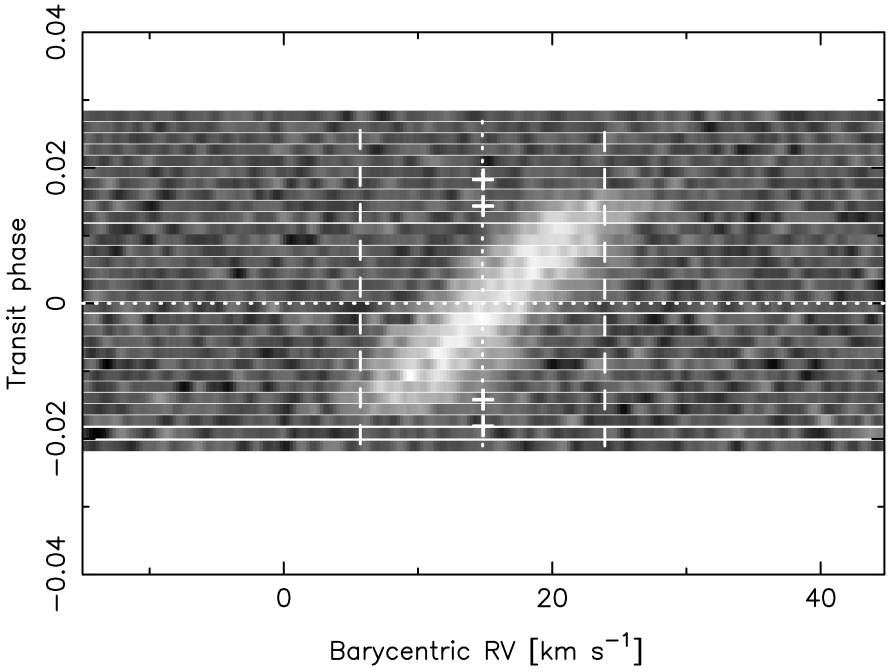




- vsinI = 10.5±0.4 km/s
- $\lambda = 4.8^{o}\ ^{+12.6}_{-13.4}$

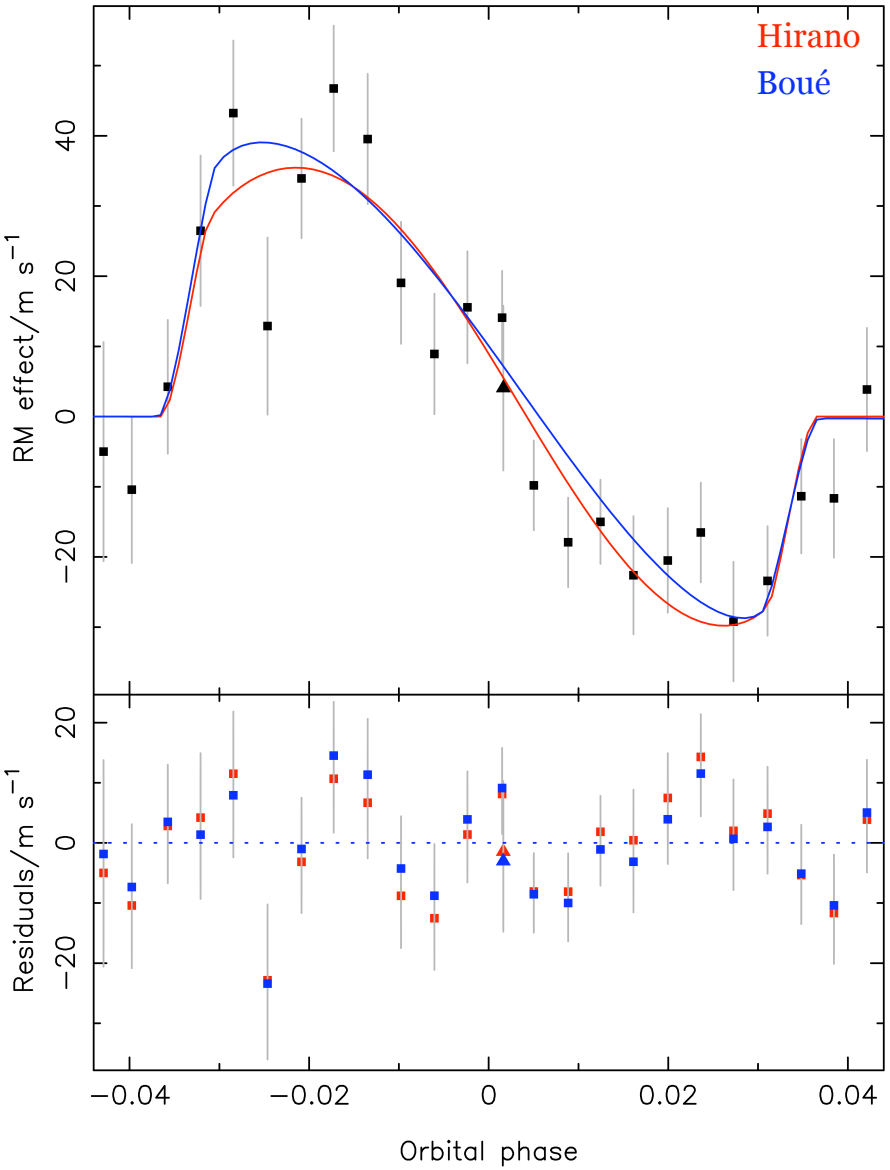
WASP-62

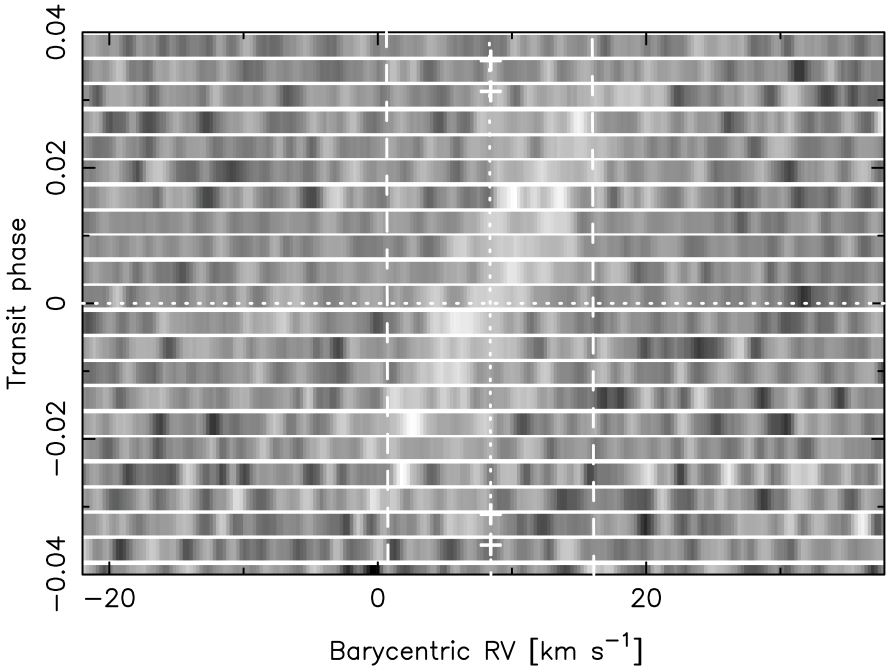




- vsinI = 9.1±0.4 km/s
- $\lambda = 18.9^{o}\ ^{+4.0}_{-3.1}$

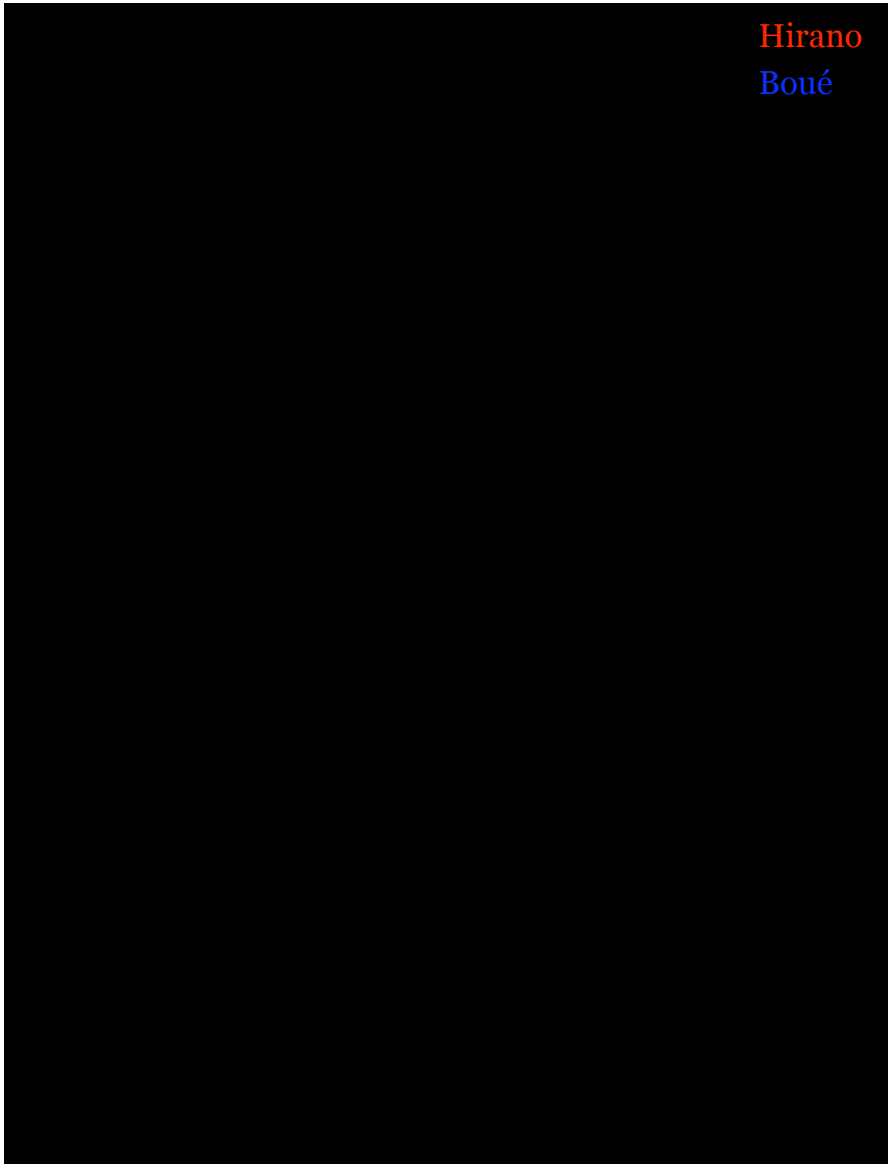
WASP-71





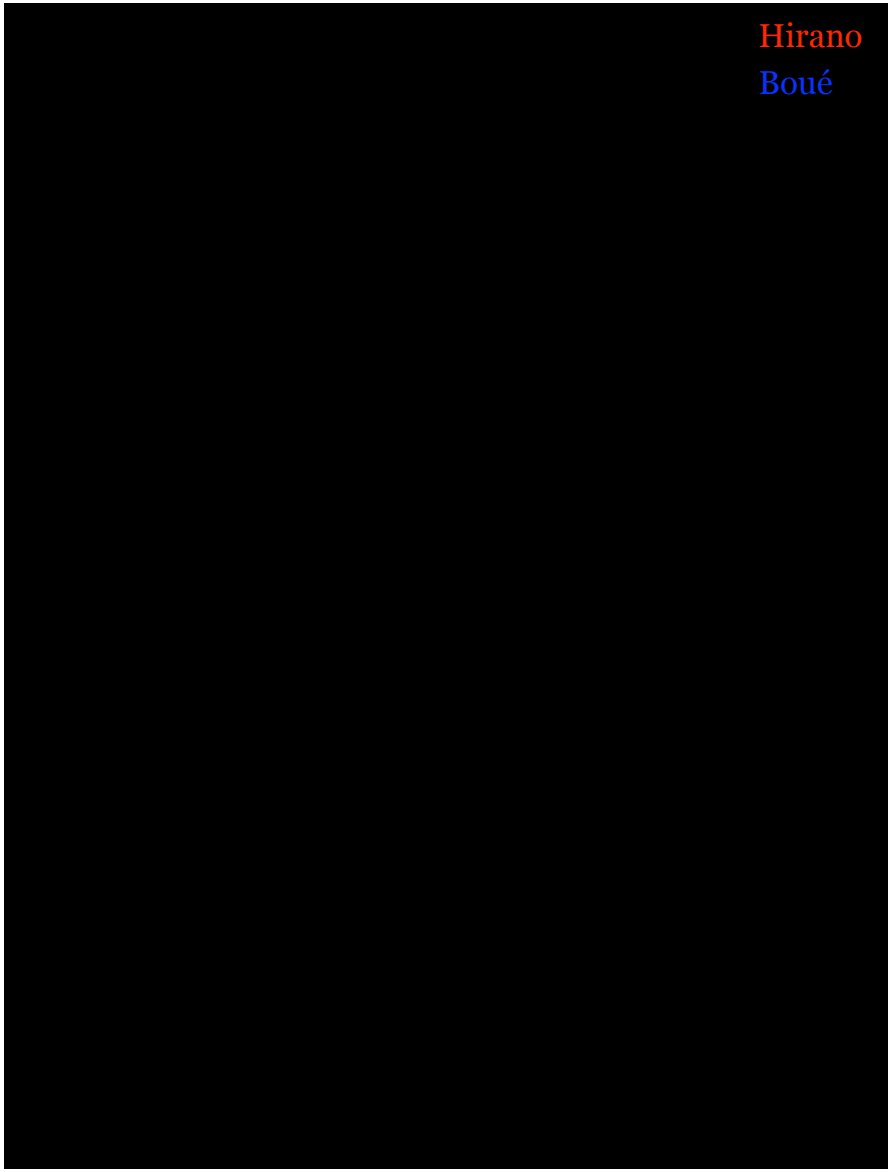
- vsinI = 7.7±0.4 km/s
- $\lambda = -3.8^{o}\ ^{+9.3}_{-11.4}$

WASP-76



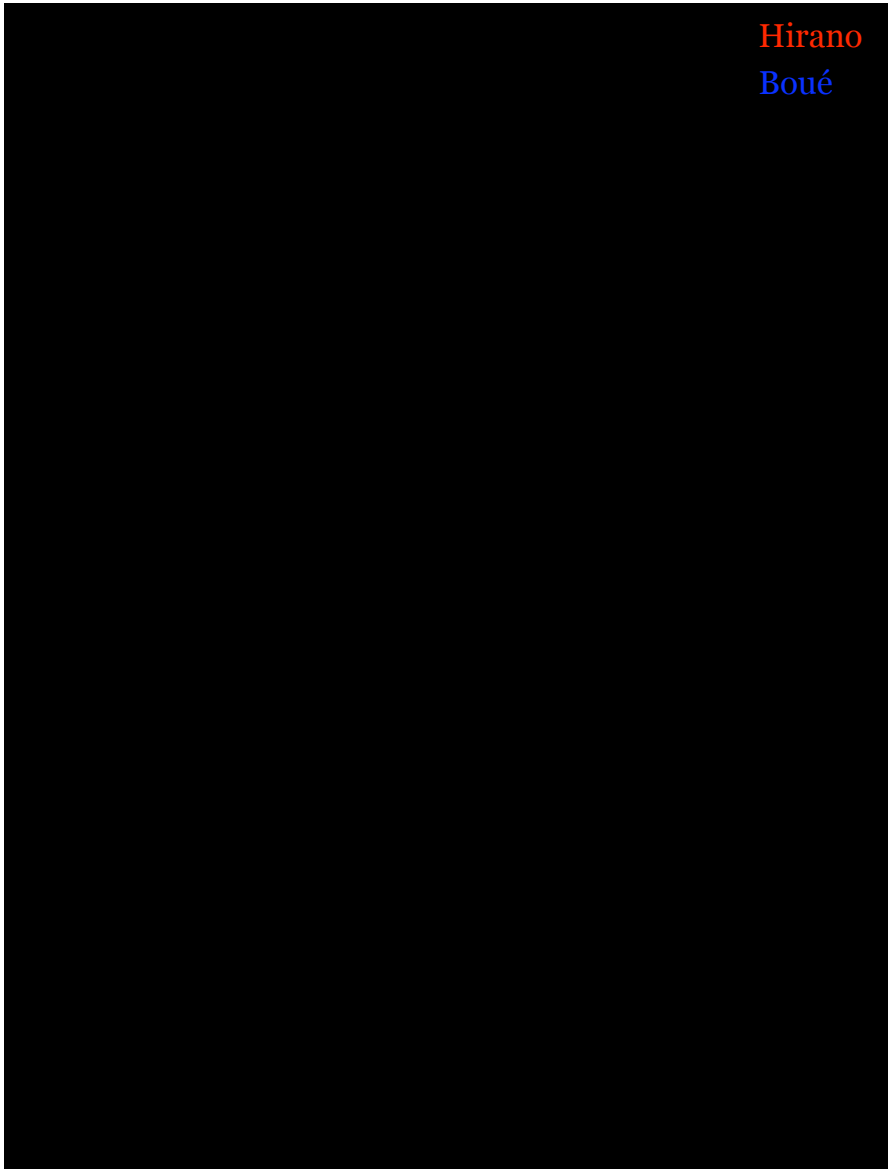
- vsinI = 2.4±0.4 km/s
- $\lambda = -77.3^{0\ +4.5}_{\ -3.6}$

WASP-78



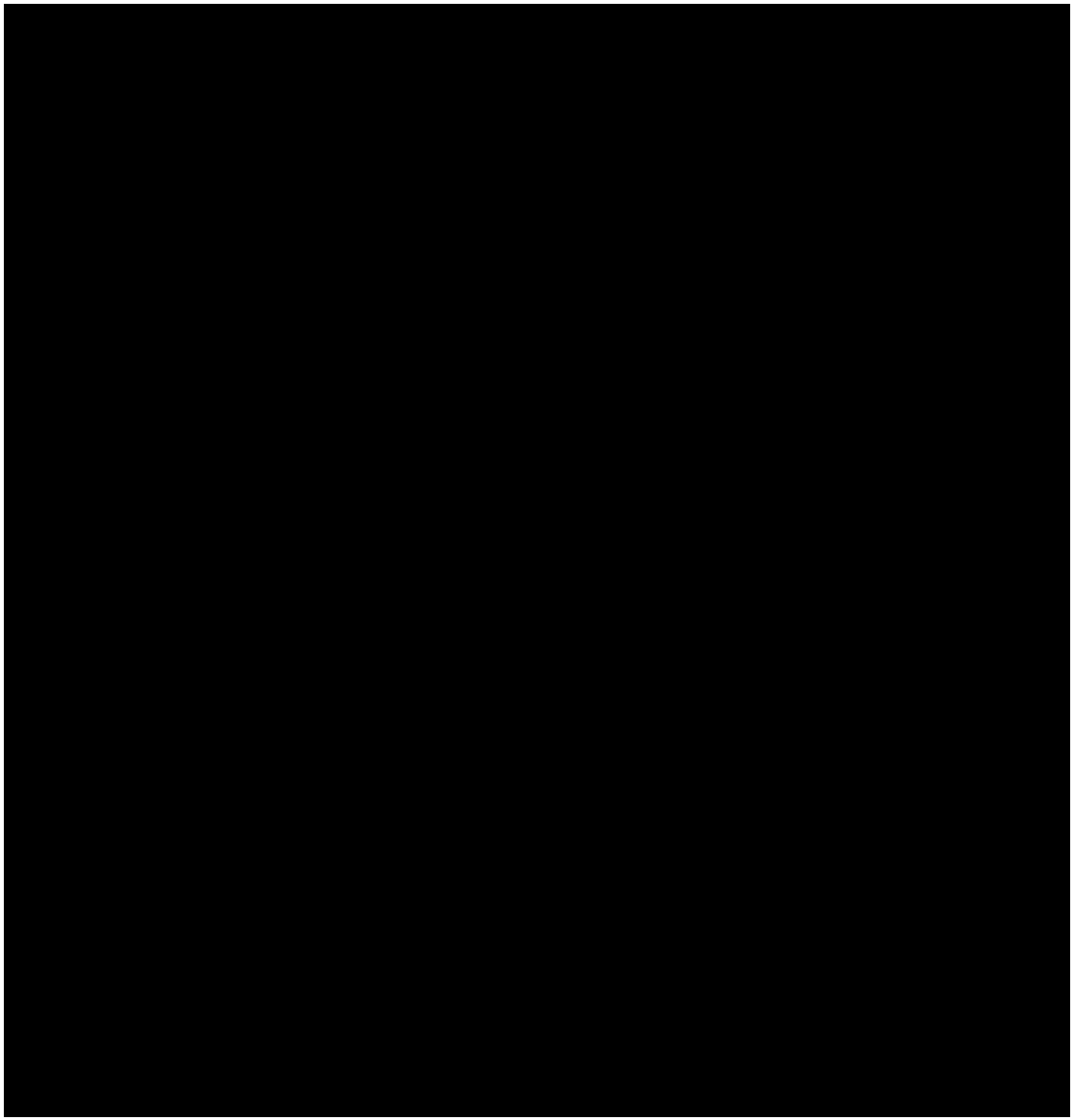
- vsinI = 7.3±0.4 km/s
- $\lambda = -6.5^{o\ +13.1}_{\ -11.9}$

WASP-79



- vsinI = 19.8±0.4 km/s
- λ = -95.4°±1.1

How do they fit in?



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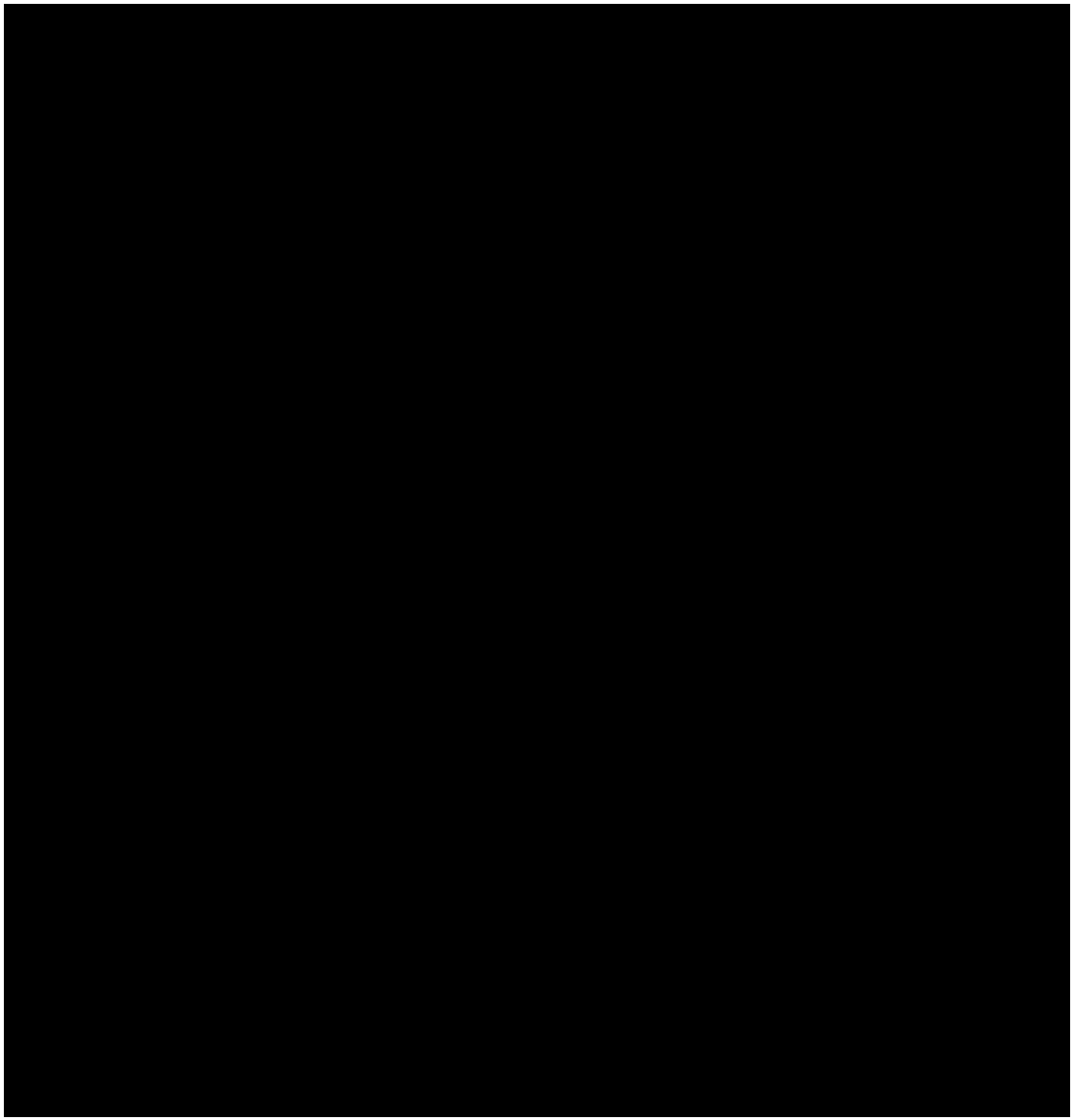

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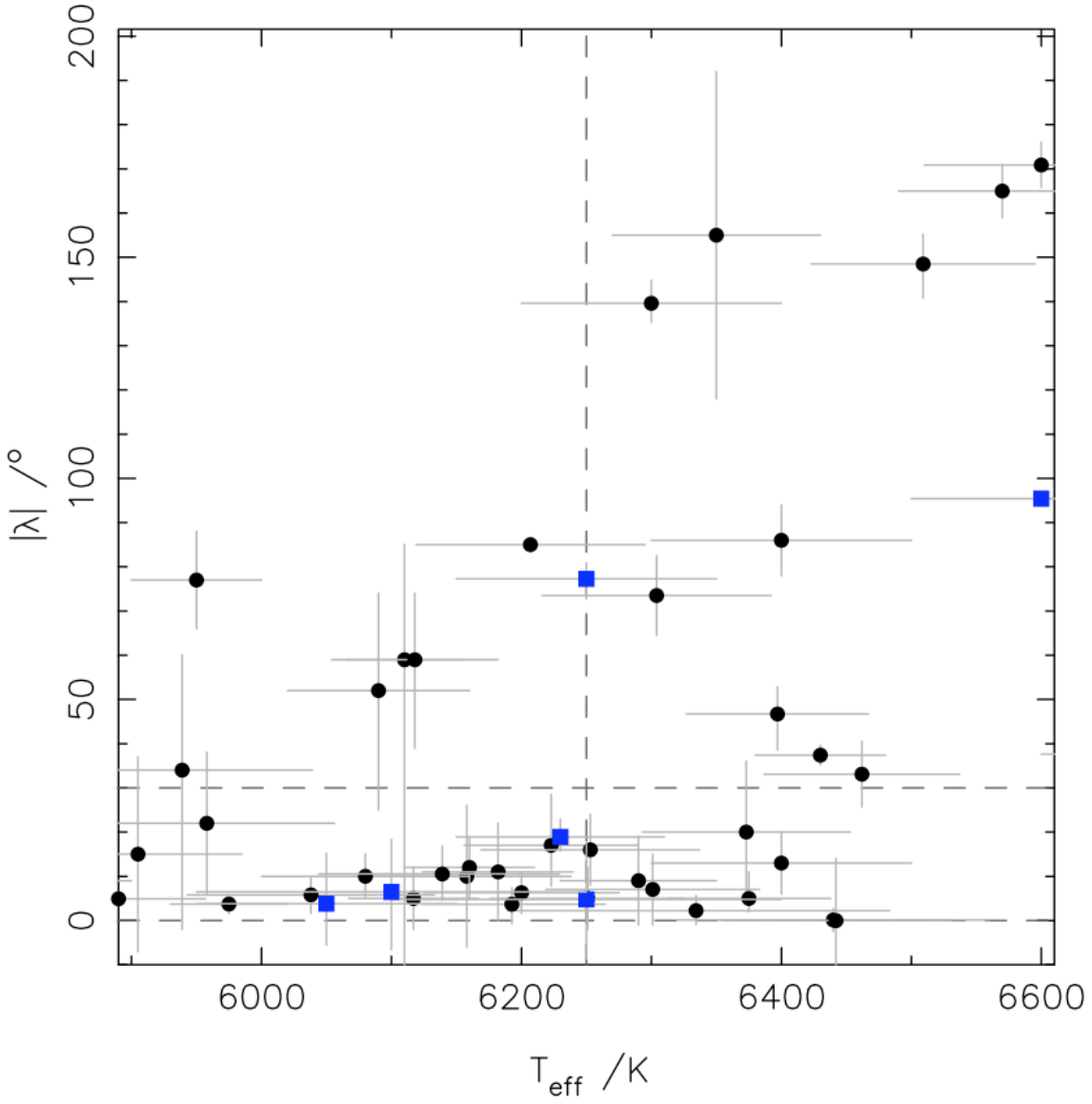
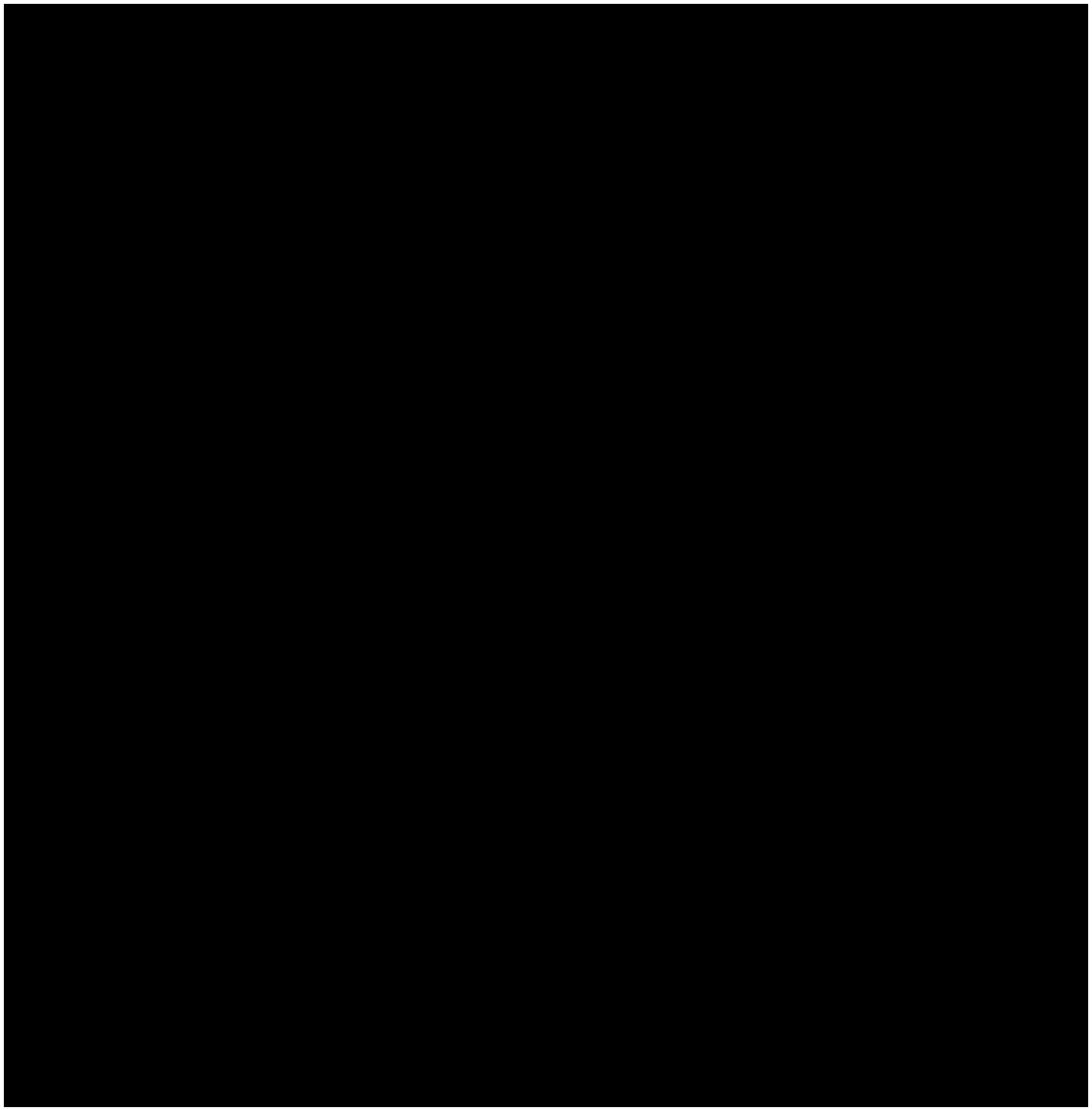


Summary

- 6 measurements of spin-orbit alignment.
  - Focused on region surrounding critical T_{eff} dividing 'hot' and 'cool' populations.
  - 4 new results.
  - Agreement with previous results for 2 systems.
  - 4 aligned, 1 strongly misaligned, 1 retrograde orbit.
- Potential extra information regarding transition from aligned to misaligned populations.
  - Analysis ongoing.

How do they fit in?



Line fit
$\chi^2 = 197$

Polynomial fit
$\chi^2_{(n=6)} = 4524$

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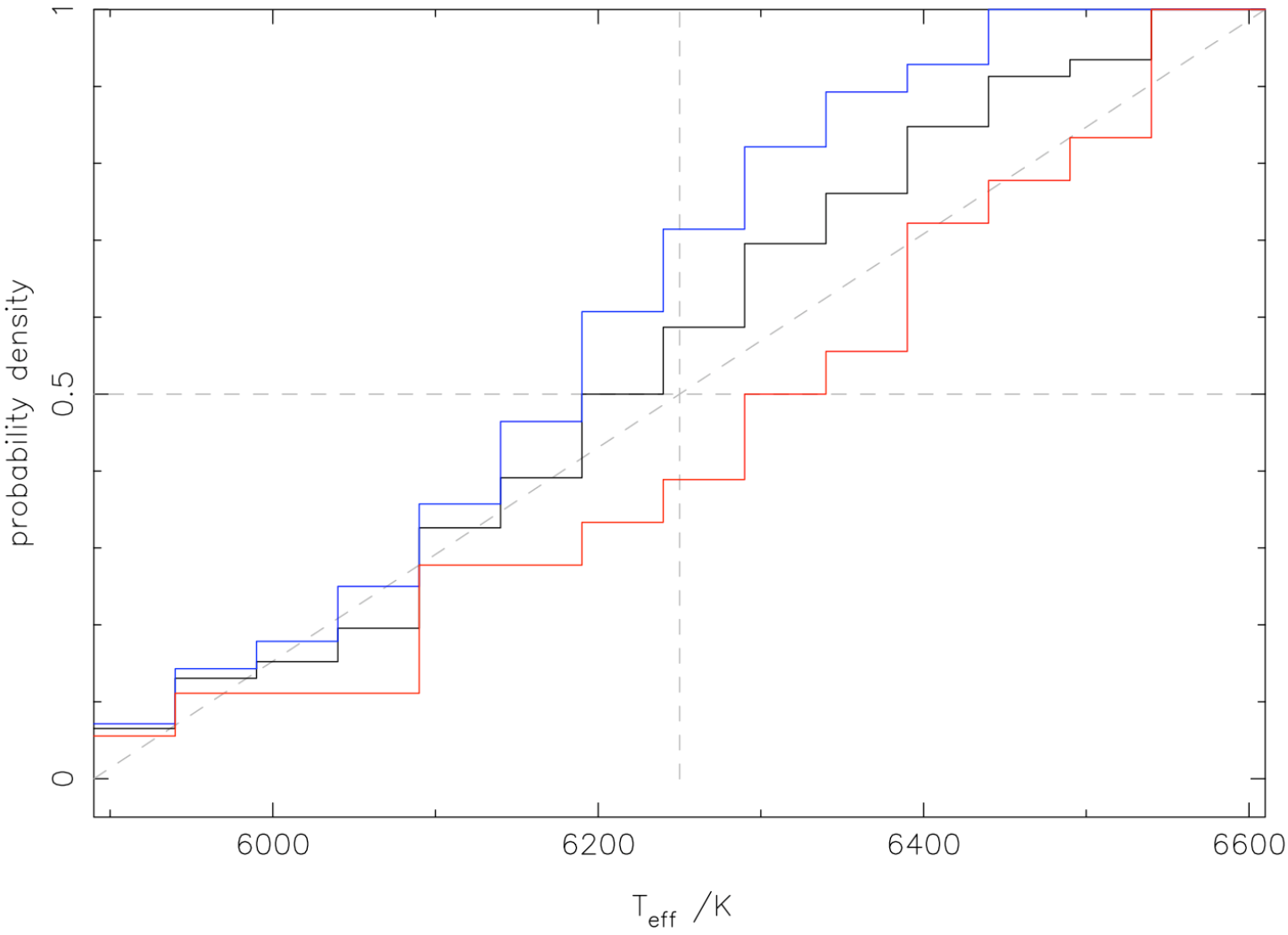

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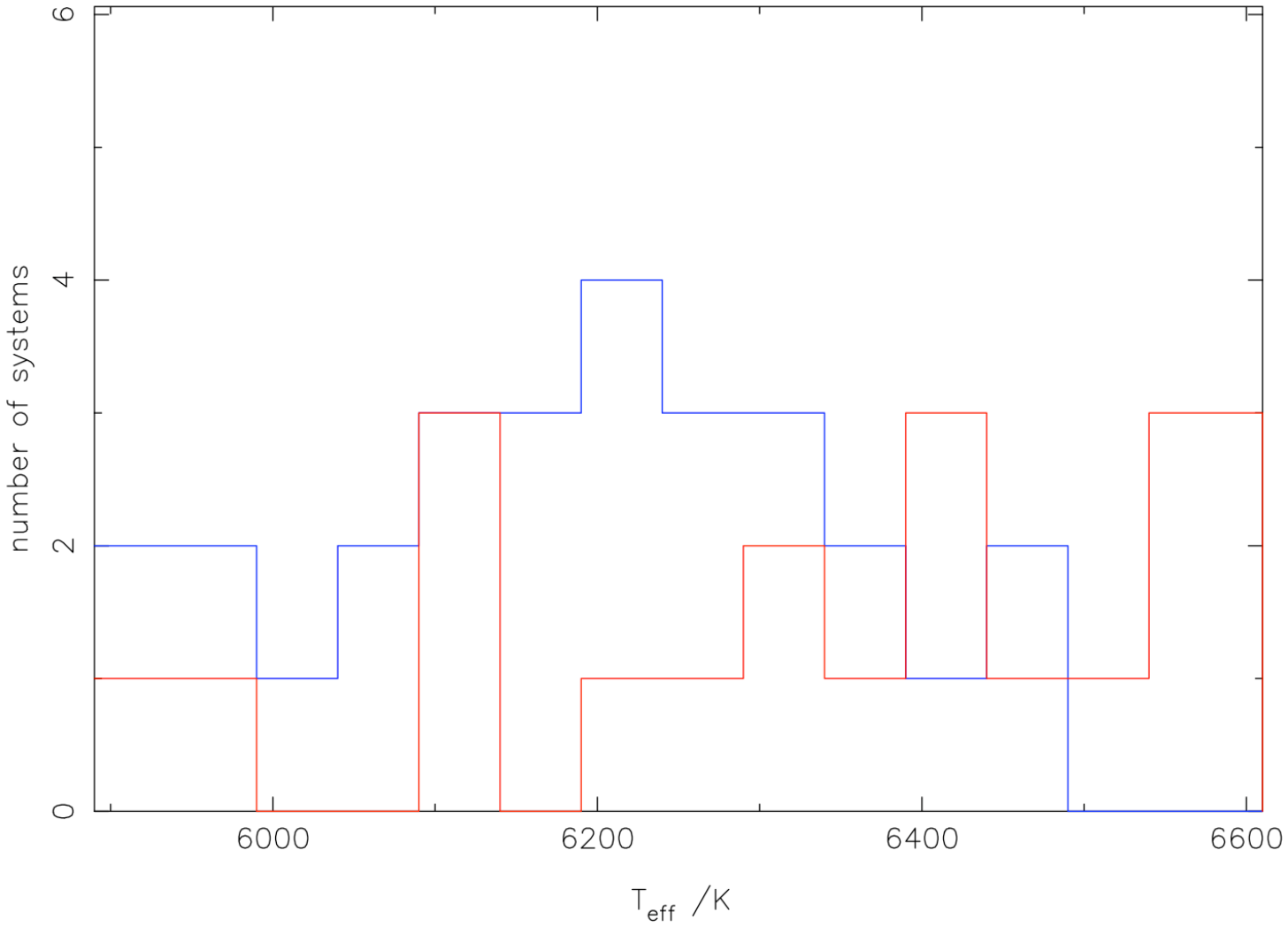

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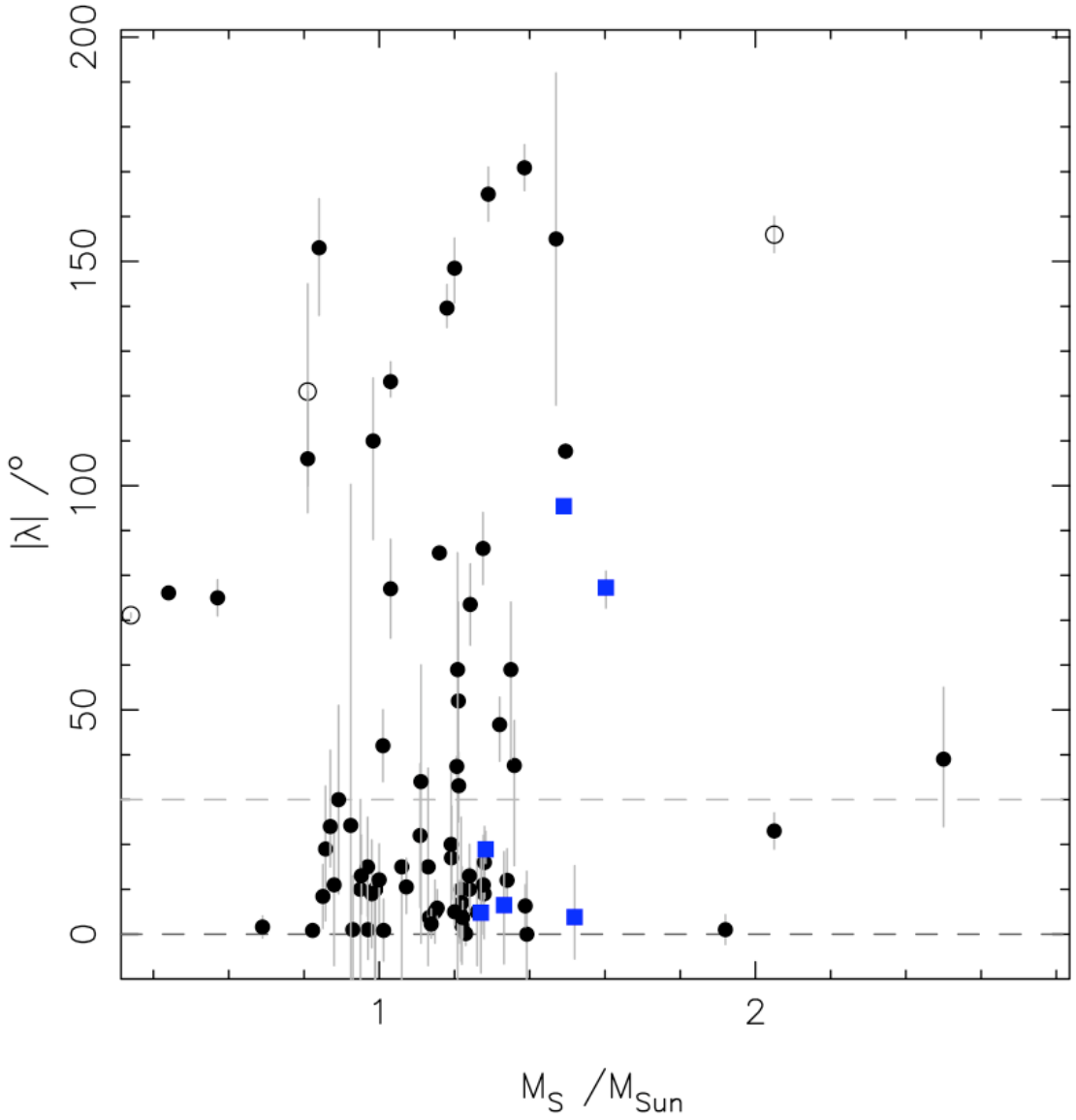

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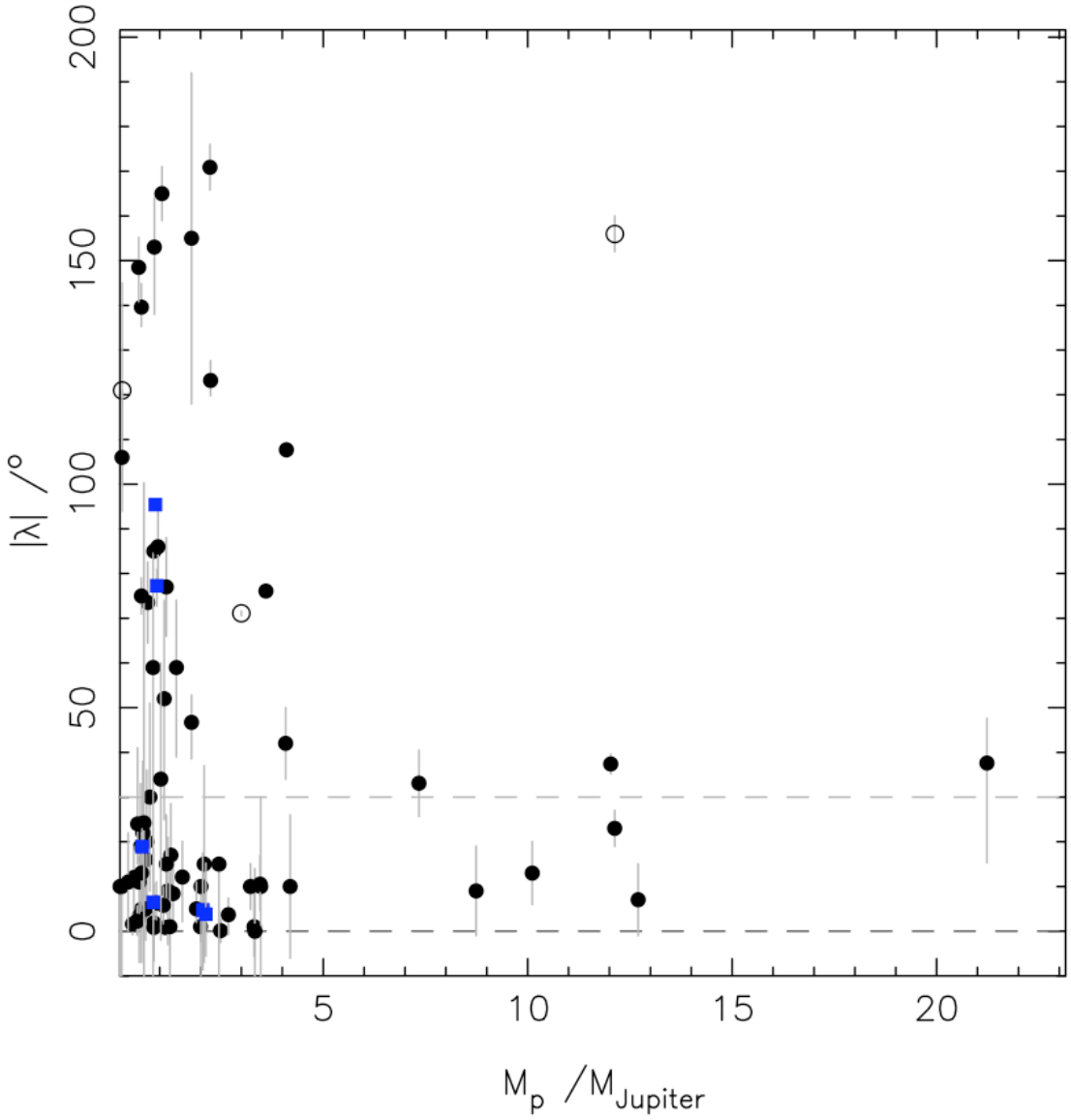

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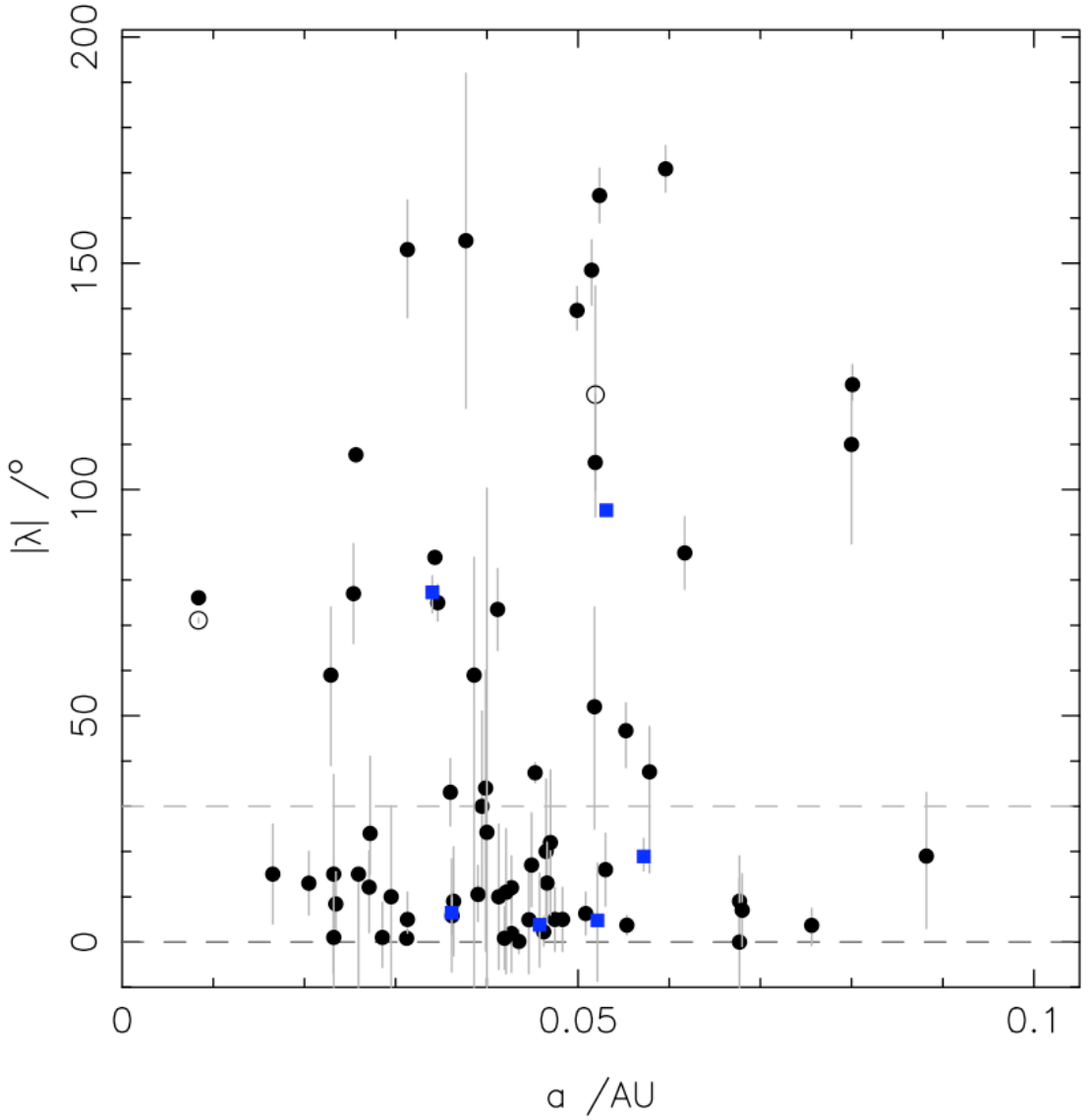

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